Second Semester Examination
Academic Session 2017/2018

May/June 2018

EPM 212 – Metrology and Quality Control
[Metrologi dan Kawalan Kualiti]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists ELEVEN [11] printed pages and TWO [2] page Appendix before you begin the examination.

[sila pastikan bahawa kertas soalan ini mengandungi SEBELAS [11] mukasurat bercetak dan DUA [2] mukasurat Lampiran sebelum anda memulakan peperiksaan.]

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

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1. [a] Explain the following terms used in dimensional metrology:

(i) resolution
(ii) sensitivity
(iii) precision
(iv) accuracy
(v) reproducibility

Terangkan sebutan-sebutan berikut yang digunakan dalam metrologi dimensi:

(i) resolusi
(ii) kepekaan
(iii) kepersisan
(iv) kejituan
(v) kebolehkeluaran semula

(20 marks/*markah***)**

[b] A vernier caliper needs to be designed with a resolution of 0.01 mm. The smallest division on the main scale has a length of 0.5 mm. Determine the number of divisions required on the vernier scale and the corresponding number of divisions on the main scale to obtain the required resolution. Hence, explain why the resolution of a vernier caliper is limited to 0.02 mm.

Angkup vernier perlu direka bentuk dengan resolusi 0.01 mm. Bahagian terkecil pada skala utama mempunyai jarak 0.5 mm. Tentukan bilangan bahagian yang diperlukan pada skala vernier dan bilangan bahagian yang sepadan pada skala utama untuk mendapatkan resolusi yang diperlukan. Seterusnya, terangkan kenapa resolusi sebuah angkup vernier dihadkan kepada 0.02 mm.

(20 marks/*markah***)**

[c] A technician measured the diameter of a coin using a digital micrometer made of aluminum alloy. The measurement was carried out at a room temperature of 32°C. Given the following data, determine the error in the micrometer reading caused by the room temperature.

True diameter of coin = 5.250 mm
Calibration temperature of micrometer = 20°C
Thermal expansion coefficient of coin material = 14.2×10^{-6} / °C
Thermal expansion coefficient of aluminum alloy = 22.5×10^{-6} / °C

Give ONE(1) method of eliminating the above error.

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Seorang juruteknik telah mengukur garispusat duit syiling dengan menggunakan mikrometer digital yang diperbuat daripada aloi aluminum. Pengukuran tersebut telah dijalankan pada suhu bilik 32℃. Diberikan data berikut, tentukan ralat dalam bacaan micrometer disebabkan oleh suhu bilik.

Garispusat sebenar duit syiling = 5.250 mm
Suhu kalibrasi micrometer = 20℃
Pekali pengembangan termal bahan duit syiling = 14.2 × 10^{-6}/ ℃
Pekali pengembangan termal aloi aluminum = 22.5 × 10^{-6}/ ℃

Berikan SATU(1) cara untuk menghapuskan ralat tersebut.

(20 marks/*markah***)**

[d] State TWO(2) factors that determine the number and spacing of fringes observed when an optical flat is placed on top of a polished surface and the combination is viewed under a monochromatic light source.

Nyatakan DUA(2) faktor yang menentukan bilangan dan jarak pinggir-pinggir yang diperhatikan apabila keping optik diletakkan ke atas permukaan yang digilap dan susunan tersebut dipandang di bawah punca cahaya monokromatik.

(10 marks/*markah***)**

[e] Figure Q1[e] shows the fringe pattern formed when an optical flat is placed on a test surface and viewed under sodium lamp (λ = 0.585 μm). Sketch cross-sections along lines A-A, B-B and C-C to show the profile of the surface. Hence, determine the height difference between the highest and the lowest points along each section.

Rajah S1[e] menunjukkan corak pinggir yang terbentuk apabila keping optik diletakkan ke atas permukaan ujian dan dipandang di bawah cahaya natrium (λ = 0.585 μm). Lakarkan keratan rentas sepanjang garisan A-A, B-B dan C-C untuk menunjukkan profil permukaan tersebut. Seterusnya, tentukan perbezaan ketinggian di antara titik-titik tertinggi dan terendah sepanjang setiap bahagian.

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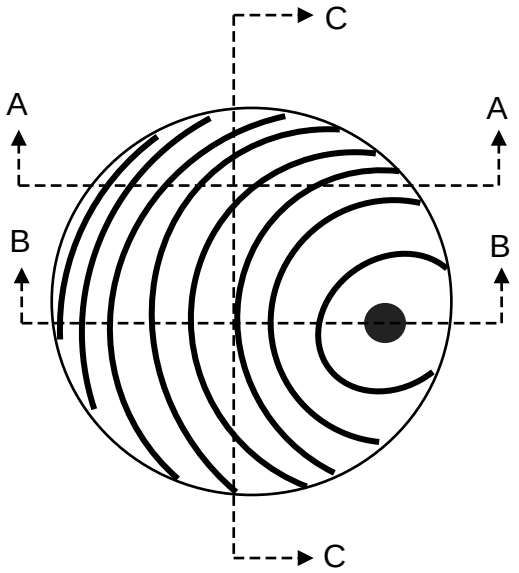

Figure Q1[e]
Rajah S1[e]

(30 marks/*markah***)**

2. [a] State the principle of alignment (Abbe's rule). Give TWO(2) examples of instruments that do not obey this principle.

Nyatakan prinsip penjajaran (petua Abbe). Berikan DUA(2) contoh alatan yang tidak mematuhi prinsip ini.

(10 marks/*markah***)**

[b] A screw gauge micrometer needs to be designed with a resolution of 0.001 mm. Determine the suitable combination of pitch of the screw thread and number of divisions on the thimble required to achieve this resolution.

Sebuah mikrometer tolok skru perlu direkabentuk dengan resolusi 0.001 mm. Tentukan kombinasi pic ulir skru dan bilangan bahagian pada thimble untuk mencapai resolusi ini.

(20 marks/*markah***)**

[c] Give THREE(3) reasons why the average roughness (R_a) parameter is not the best parameter for roughness measurement.

Figure Q2[c] shows a trace obtained using a skidded-type roughness tester on a brake pad. The sampling length used in the measurement is 2.5 mm. Determine the following roughness parameter from the trace: (i) R_z (based on ISO4287:1997) (ii) R_q and (iii) R_{sk}. Which of these parameter accurately reflect the functional characteristic of the surface? Why?

…5/-

Berikan TIGA(3) sebab kenapa parameter kekasaran purata (R_a) bukan parameter yang terbaik untuk pengukuran kekasaran.

Rajah S2[c] menunjukkan surih yang didapati dengan menggunakan penguji kekasaran jenis tanpa penggelincir pada permukaan alas brek. Jarak pensampelan yang digunakan dalam pengukuran tersebut ialah 2.5 mm. Tentukan parameter-parameter kekasaran berikut daripada surih tersebut: (i) R_z (berasaskan ISO4287:1997) (ii) R_q dan (iii) R_{sk}. Manakah di antara parameter-parameter tersebut yang mencerminkan dengan tepat ciri fungsi permukaan tersebut? Kenapa?

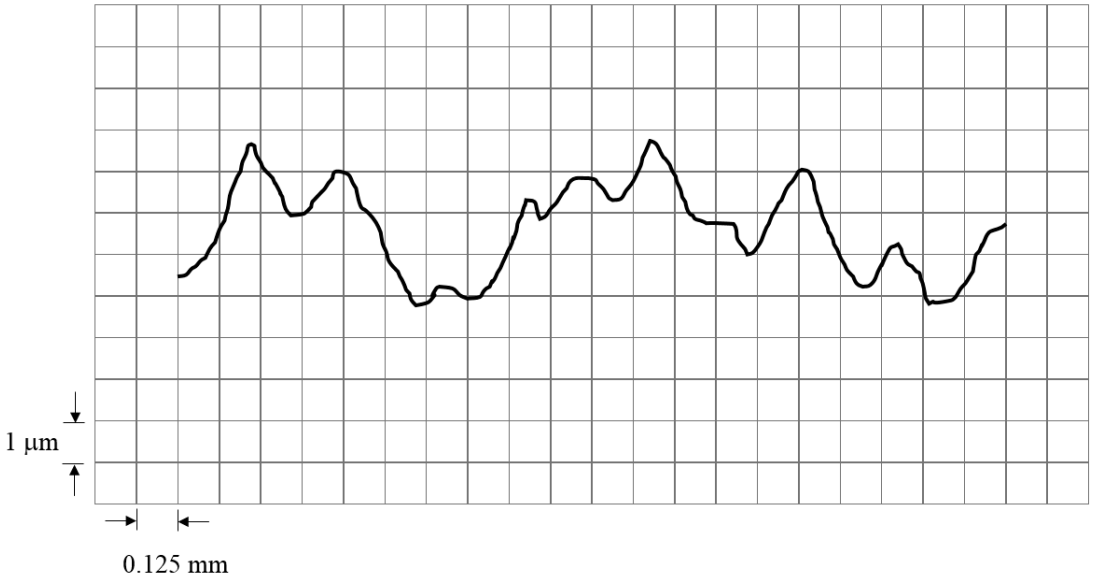

Figure Q2[c]
Rajah S2[c]

(40 marks/*markah***)**

[d] With the aid of diagrams, explain the difference between the following types of roundness measurement methods: Least-squares circle (LSC) method, maximum inscribing circle (MIC) method, minimum circumscribing circle (MCC) method and minimum zone reference circle (MZC) method.

Figures Q2[d](i)&(ii) (Appendix A) show a trace obtained from a roundness tester. Determine the roundness error using the MCC method for Figure Q2[d](i) and the MIC method for Figure Q2[d](ii).
Detach Appendix A and attached it together with your answer script.

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Dengan bantuan lakaran, terangkan perbezaan antara kaedah-kaedah pengukuran kebulatan berikut: Kaedah bulatan kuasadua terkecil (LSC), kaedah bulatan dalaman maksimum (MIC), kaedah bulatan luaran minimum (MCC) dan kaedah bulatan zon minimum rujukan (MZC).

Rajah-rajah S2[d](i)&(ii) (Apendiks A) menunjukkan surih yang diperoleh daripada penguji kebulatan. Tentukan ralat kebulatan dengan menggunakan kaedah MCC untuk Rajah S2[d](i) dan kaedah MIC untuk Rajah S2[d](ii).
Asingkan Apendiks A dan lampirkan bersama skrip jawapan anda.

(30 marks/*markah***)**

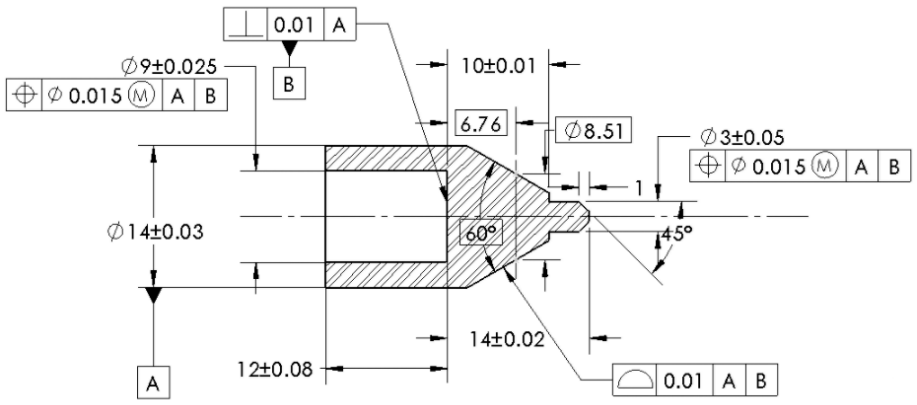
3. [a] State the FIVE(5) types of dimensioning control in geometric dimensioning and tolerancing (GD&T).

Nyatakan LIMA(5) jenis kawalan pendimensian dalam pendimensian dan pentoleransi geometri (GD&T).

(10 marks/*markah***)**

[b] Figures Q3[b](i)&(ii) show engineering drawings containing several types of feature control frames. Explain the meaning of the feature control frames in each drawing. Note : Redraw the feature control frames.

Rajah-rajah S3[b](i)&(ii) menunjukkan lukisan kejuruteraan yang mengandungi bingkai kawalan ciri. Terangkan makna bingkai-bingkai kawalan ciri dalam setiap lukisan. Nota : Lukiskan semula bingkai-bingkai kawalan ciri tersebut.



(Source: http://blogs.solidworks.com)

Figure Q3[b](i)
Rajah S3[b](i)

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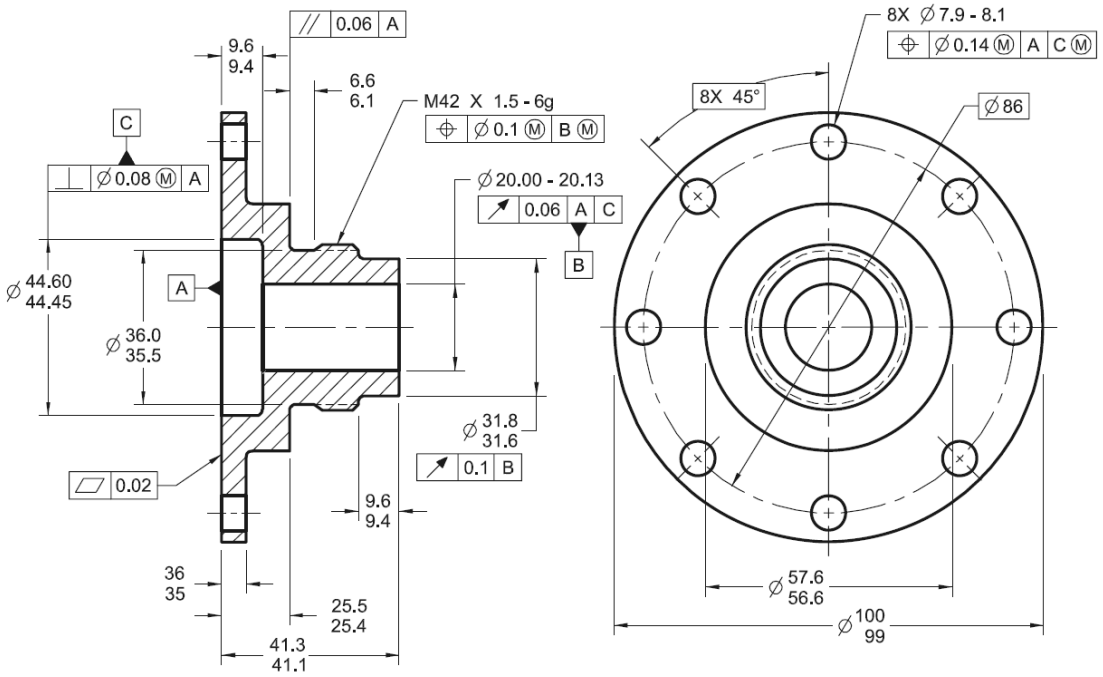

(Source: www.grabcad.com)

Figure Q3[b](ii)

Rajah S3[b](ii)

(40 marks/*markah*)

[c] **Pareto method is used in the inspection for respiratory masks during a given time period. The following defects are noted: Discolouration, loose strap, dents, tears and pin holes as shown in Table Q3[c]. Plot the Pareto chart and analyse the two types of defects that should receive the most attention. How would you recommend the corrective and prevention activities for the defects?**

Kaedah Pareto digunakan dalam pemeriksaan untuk topeng pernafasan dalam tempoh masa tertentu. Kecacatan berikut dicatatkan: Penyahwarnaan, tali longgar, kemek, koyak dan lubang-lubang pin seperti yang ditunjukkan dalam Jadual S3 [c]. Plot graf Pareto dan analisa kedua-dua jenis kecacatan yang perlu mendapat perhatian terbanyak. Bagaimana anda akan cadangkan aktiviti pembetulan dan pencegahan bagi kecacatan tersebut?

Table Q3[c]
Jadual S3[c]

Discolouration	Discolouration	Discolouration
Loose Strap	Loose Strap	Loose Strap
Discolouration	Dent	Loose Strap
Discolouration	Loose Strap	Discolouration
Loose Strap	Discolouration	Discolouration
Discolouration	Discolouration	Dent
Discolouration	Dent	Tear
Tear	Pinhole	Discolouration
Dent	Discolouration	Pinhole
Discolouration	Tear	Tear

(50 marks/*markah*)

4. [a] List and define seven Quality Control (QC) tools into data analysis tool and cause analysis tool.

Senaraikan dan berikan definasi tujuh alat kawalan mutu yang menjadi alat analisis data dan alat untuk menganalisa sebab.

(**20 marks**/*markah*)

[b] Two operators have taken three measurements for each of 10 parts number as shown in Table Q4[b]. Use Appendix B for references in answering the questions.

Dua pengendali telah mengambil tiga ukuran bagi setiap 10 bahagian nombor seperti yang ditunjukkan dalam Jadual S4[b]. Gunakan Apendiks B sebagai rujukan untuk menjawab soalan-soalan.

Table Q4[b]
Jadual S4 [b]

Part number	**Operator 1 Measurements** *(mm)*			**Operator 2 Measurements** *(mm)*		
	1	**2**	**3**	**1**	**2**	**3**
1	50	49	50	50	48	51
2	52	52	51	51	51	51
3	53	50	50	54	52	51
4	49	51	50	48	50	51
5	48	49	48	48	49	48
6	52	50	50	52	50	50
7	51	51	51	51	50	50
8	52	50	49	53	48	50
9	50	51	50	51	48	49
10	47	46	49	46	47	48

…9/-

(i) With the help of plotted graphs, determine the standard deviation, control chart and central limit of the measurement error in the collected data.

Dengan bantuan grap yang di plotkan, kirakan sisihan piawai, carta kawalan dan had tengah ralat pengukuran yang boleh didapati daripada data yang terkumpul.

(**40 marks**/*markah*)

(ii) If the specification are at $50 \pm 10mm$, comment on the gauge specification?

Jika spesifikasi adalah pada 50 ± 10 mm, ulas mengenai spesifikasi tolok?

(20 marks/*markah*)

(iii) Does the control chart analysis of the data indicate any potential problem in using the gauge? Justify your answer.

Adakah analisis carta kawalan data menunjukkan apa-apa masalah yang berpotensi dalam menggunakan tolok. Berikan justifikasi anda.

(**20 marks**/*markah*)

5. [a] Sketch a diagram showing a comparison of normal (*N*), tightened (*T*) and reduced (*R*) curves and explain the pros and cons of using acceptance sampling procedures compared to traditional quality inspection.

Lukiskan gambarajah menunjukkan graf perbandingan biasa (N), diperketat (T) dan dikurangkan (R) dan terangkan kebaikan dan keburukan menggunakan tatacara penerimaan pengsampelan berbanding menjalani pemeriksaan kualiti tradisional.

(**20 marks**/*markah*)

[b] An experiment has been carried out to monitor the temperature dependence of the resistance of a rheomagneto-rubber bearing. The ideal variation is represented by:

$$R=R_o(1 + \alpha T)$$

where R is the resistance of temperature T (^oC), R_o is the resistance at 0 ^oC and α is the temperature coefficient of resistance. The following observations of R and T were obtained as in Table Q5[b]:

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Satu eksperimen telah dijalankan untuk memantau pergantungan suhu rintangan galas rheomagneto-getah. Perubahan sesuai diwakili oleh:

$$R=R_o(1 + \alpha T)$$

di mana R adalah rintangan T suhu (^oC), R_o adalah rintangan pada 0 ^oC dan α is pekali suhu rintangan. Pemerhatian berikut pada R dan T diperolehi seperti dalam Jadual S5 [b].

Table Q5[b]
Jadual S5[b]

Temperature (^oC)	**Three set of resistance R readings** (Ω)		
10	12.4	12.3	12.5
20	13.2	13.0	13.1
30	13.5	13.6	13.7
40	13.7	13.8	13.9
50	14.5	14.6	14.6
60	15.1	15.3	15.2
70	15.4	15.5	15.3
80	16.2	16.1	16.0

(i) Plot $\bar{x}$ and R charts for this data collected in Table Q5[b]. Is the process in statistical control? Give your comment on the plotted graphs.

Plotkan carta $\bar{x}$ dan R untuk data-data terkumpul di Jadual S5[b]. Adalah proses ini di dalam kawalan statistik? Berikan komen anda ke atas graf yang diplotkan itu.

(**40 marks**/*markah*)

(ii) Determine the process standard deviation using the range method.
Kirakan sisihan piawai proses dengan menggunakan kaedah julat.

(**20 marks**/*markah*)

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(iii) Determine the process capability ratio, C_p. If the specifications are at nominal $\pm$100, justify your opinion on the capability of the process.

Kirakan nisbah keupayaan proses, C_p. Jika spesifikasi yang berada di nominal ±100, ulaskan pendapat anda mengenai keupayaan proses itu.

(**20 marks** /*markah*)

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APPENDIX A / *LAMPIRAN A*

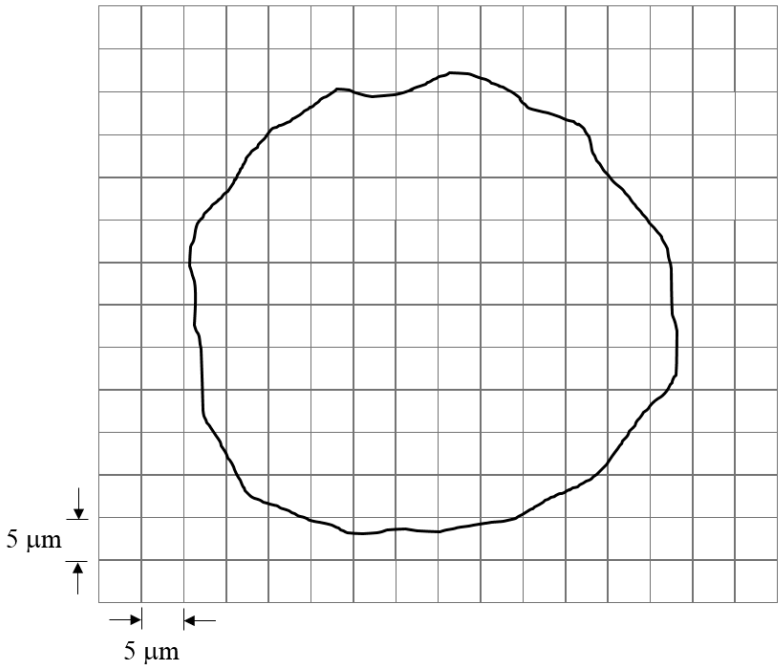

Figure Q2[d](i)
Rajah S2[d](i)

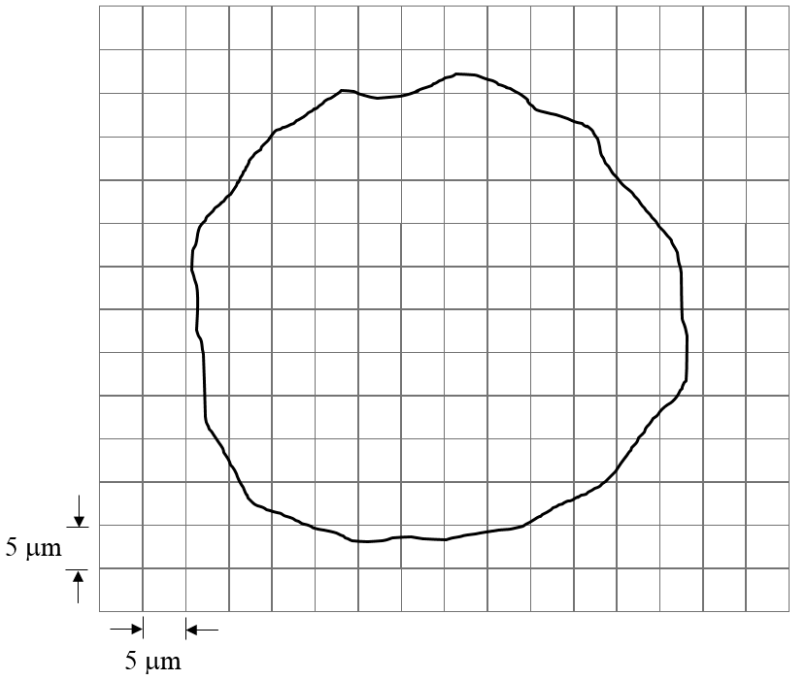

Figure Q2[d](ii)
Rajah S2[d](ii)

Detach Appendix A and attached it together with your answer script.
Asingkan Apendiks A dan lampirkan bersama skrip jawapan anda.

APPENDIX B / *LAMPIRAN B*

Factors for Constructing Variables Control Charts

Observations in Sample, n	Chart for Averages: Factors for Control Limits A	A_2	A_3	Factors for Center Line c_4	$1/c_4$	Chart for Standard Deviations: Factors for Control Limits B_3	B_4	B_5	B_6	Factors for Center Line d_2	$1/d_2$	Chart for Ranges: Factors for Control Limits d_3	D_1	D_2	D_3	D_4
2	2.121	1.880	2.659	0.7979	1.2533	0	3.267	0	2.606	1.128	0.8865	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	1.693	0.5907	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	2.059	0.4857	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	2.326	0.4299	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	2.534	0.3946	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	2.704	0.3698	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	2.847	0.3512	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	2.970	0.3367	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	3.078	0.3249	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	3.173	0.3152	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	3.258	0.3069	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	3.336	0.2998	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	3.407	0.2935	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	3.472	0.2880	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	3.532	0.2831	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	3.588	0.2787	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	3.640	0.2747	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	3.689	0.2711	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	3.735	0.2677	0.729	1.549	5.921	0.415	1.585
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	3.778	0.2647	0.724	1.605	5.951	0.425	1.575
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	3.819	0.2618	0.720	1.659	5.979	0.434	1.566
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	3.858	0.2592	0.716	1.710	6.006	0.443	1.557
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	3.895	0.2567	0.712	1.759	6.031	0.451	1.548
25	0.600	0.153	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	3.931	0.2544	0.708	1.806	6.056	0.459	1.541

For $n > 25$,

$$A = \frac{3}{\sqrt{n}} \qquad A_3 = \frac{3}{c_4\sqrt{n}} \qquad c_4 \cong \frac{4(n-1)}{4n-3}$$

$$B_3 = 1 - \frac{3}{c_4\sqrt{2(n-1)}} \qquad B_4 = 1 + \frac{3}{c_4\sqrt{2(n-1)}}$$

$$B_5 = c_4 - \frac{3}{\sqrt{2(n-1)}} \qquad B_6 = c_4 + \frac{3}{\sqrt{2(n-1)}}$$